An Uplink Operational Concept for a State-Based Software Architecture

Mission Data System (MDS) is a project of NASA's Jet Propulsion Laboratory. MDS will provide a state-based, end-to-end architecture for planetary mission software. "State-based" means that the mission system to be controlled is systematically analyzed and designed in terms of the states of the system. Analysis of the system focuses on defining states of interest in the mission, how these states are estimated, and how these states are controlled. States may be as simple as On/Off states of power switches, or may be as complicated as the trajectory of the spacecraft, or the contents of the project data repository.

Control of the mission system is specified in terms of "goals" on states, which represent constraints on acceptable states over periods of time. High-level goals on system state (such as presence of particular observations in the project data repository) will elaborate into subgoals on other states of the system over time (e.g. pointing direction, instrument power state, presence of an observation in onboard storage, status of a downlink to Earth, and reception of the observation on Earth.) Elaboration of a set of goals will result in a network of overlapping goals on the same state; a scheduling and merging process is used to determine if these overlapping goals are compatible. The MDS goal net allows for arbitrary combinations of event-based and time-based "sequencing".

The state-and-goal analysis of the MDS architecture makes three concepts explicit: intent, persistence, and dependence. "Intent" means that the desired state is conveyed explicitly, rather than as the implicit result of a command. (E.g. a goal to have a device powered on, instead of a command to turn on the device). "Persistence" means that the desired state persists over a stated period of time (E.g. the device will remain powered on until explicitly desired to be powered off, as compared to a single command whose effects are presumed to persist indefinitely). "Dependence" means that the system explicitly conveys what states are dependent on other states. (E.g. a device is powered on because it is being used to control another state in the system.) These concepts are implicit in the typical sequenced-command system.

Mission uplink operations may be caricatured as the process of preparing plans to cover a particular part of the mission, evaluating whether these plans are likely to succeed (given resource limitations and flight rules and constraints), and uplinking the resulting plans. Within the MDS architecture, these steps will be performed by elaborating goals, and checking the compatibility and achievability of overlapping goals. These checks will use the same information typically developed for space mission operations, and captured in ad hoc tools. The MDS architecture provides a uniform structure for capturing and using this information.

The Mars Smart Rover project, launching in 2009, is currently planned as the first MDS customer. This project will land a vehicle on Mars within 5-km. of a target site and will deploy a highly-autonomous rover to travel up to 450 meters/sol over a full Martian year or more. Particular challenges include:

a.) validating event-based plans in the presence of uncertainty in exactly how long particular activities will take;
b.) selecting appropriate levels of detail in evaluating plans for highly autonomous flight systems;
c.) prioritizing activities to take maximum advantage of uncertainty in mission plans, so that lower-priority activities are dropped if in conflict with higher-priority activities.